

CLAIMS

What is claimed is:

1. A control circuit for controlling a motor, the control circuit comprising:  
a contactor circuit including a contactor and having first and second ends; and  
5 a snubber circuit connected across the contactor circuit, the snubber circuit including

a first port electrically connected to the first end of the contactor circuit,

10 a second port electrically connected to the second end of the contactor circuit,

15 a first sub-circuit electrically connected to one of the first and second ports, the first sub-circuit including a resistor and a non-linear device electrically connected in parallel branches, and

20 a second sub-circuit electrically connected in series with the first sub-circuit and to the other of the first and second ports, the second sub-circuit including an energy storage device.

- 25 2. A control circuit as set forth in claim 1 wherein the non-linear device includes a diode.

- 30 3. A control circuit as set forth in claim 1 wherein the energy storage device includes a capacitor.

4. A control circuit as set forth in claim 1 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, and wherein a substantial portion of the first current flows through the non-linear device when the first current flows through the first sub-circuit.

5. A control circuit as set forth in claim 4 wherein the energy storage device charges when the first current flows through the second sub-circuit.

6. A control circuit as set forth in claim 5 wherein the energy storage device  
discharges when the contactor is closed, wherein the energy discharged from the  
energy storage device creates a second current that flows through the first sub-circuit  
opposite the first current, and wherein a substantial portion of the second current  
flows through the resistor when the second current flows through the first sub-circuit.

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7. A control circuit as set forth in claim 1 wherein the non-linear device is a first  
diode, wherein the second sub-circuit further includes a second non-linear device, and  
wherein the energy storage device and the second non-linear device are electrically  
connected in parallel branches.

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8. A control circuit as set forth in claim 7 wherein the first and second non-linear  
devices each includes a diode, and wherein the energy storage device includes a  
capacitor.

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9. A control circuit as set forth in claim 7 wherein the snubber circuit receives a  
first current flowing from the first port through the first and second sub-circuits to the  
second port, and wherein a substantial portion of the first current flows through the  
first non-linear device when the first current flows through the first sub-circuit.

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10. A control circuit as set forth in claim 9 wherein the energy storage device  
charges when the first current flows through the second sub-circuit.

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11. A control circuit as set forth in claim 10 wherein the energy storage device  
discharges when the contactor is closed, wherein the energy discharged from the  
energy storage device creates a second current that flows through the first sub-circuit  
opposite the first current, and wherein the a substantial portion of the second current  
flows through the resistor when the second current flows through the first sub-circuit.

12. A control circuit as set forth in claim 9 wherein the snubber circuit receives a second current flowing from the second port through the first and second sub-circuits to the first port, and wherein a substantial portion of the second current flows through the second non-linear device when the second current flows through the second sub-circuit.

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13. A control circuit for controlling a motor, the control circuit comprising:  
a contactor circuit including a contactor and having first and second ends; and  
a snubber circuit connected across the contactor circuit, the snubber circuit  
including

5                    a first port electrically connected to the first end of the contactor  
circuit;

                      a second port electrically connected to the second end of the contactor  
circuit;

10                  a first sub-circuit electrically connected to one of the first and second  
ports, the first sub-circuit including a resistor and a first non-linear device electrically  
connected in parallel branches; and

15                  a second sub-circuit electrically connected in series with the first sub-  
circuit and to the other of the first and second ports, the second sub-circuit including a  
energy storage device and a second non-linear device electrically connected in  
parallel branches.

14. A control circuit as set forth in claim 13 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, wherein a substantial portion of the first current flows through the non-linear device when the first current flows through the first sub-circuit, and wherein the energy storage device charges when the first current flows through the second sub-circuit.

15. A control circuit as set forth in claim 14 wherein the energy storage device  
25 discharges when the contactor is closed, wherein the energy discharged from the  
energy storage device creates a second current that flows through the first sub-circuit  
opposite the first current, and wherein a substantial portion of the second current  
flows through the resistor when the second current flows through the first sub-circuit.

30 16. A control circuit as set forth in claim 15 wherein the first and second non-linear devices each includes a diode, and where the energy storage device includes a capacitor.

17. A control circuit for controlling a motor, the control circuit comprising:  
a contactor circuit including a contactor and having first and second ends; and  
a snubber circuit connected across the contactor circuit, the snubber circuit  
including

5 a first port electrically connected to the first end of the contactor circuit  
and operable to receive a first current flow having a first direction,

a second port electrically connected to the second end of the contactor circuit and operable to receive a second current flow having a second direction opposite the first direction,

10                   a first sub-circuit electrically connected to one of the first and second ports and including a resistor and a first diode electrically connected in circuit in parallel branches, the first diode being operable to allow a substantial portion of the first current to flow through the first diode when the first current flows through the first sub-circuit, and the resister being operable to allow a substantial portion of the second current to flow through the resistor when the second current flows through the first sub-circuit, and

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a second sub-circuit electrically connected in series with the first sub-circuit and to the other of the first and second ports, the second sub-circuit including a capacitor and a second diode electrically connected in circuit in parallel branches, the second diode being operable to allow a substantial portion of the second current to flow through the second diode when the second current flows through the first sub-circuit, and the capacitor charges when the first current flows through the second sub-circuit.

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18. A vehicle comprising:  
a motor; and  
a control circuit operable to control the motor, the control circuit including a contactor circuit having a contactor, a first end and a second end, and a snubber circuit connected across the contactor circuit, the snubber circuit including  
5 a first port electrically connected to the first end of the contactor circuit,  
a second port electrically connected to the second end of the contactor circuit,  
10 a first sub-circuit electrically connected to one of the first and second ports, the first sub-circuit including a resistor and a non-linear device electrically connected in parallel branches, and  
15 a second sub-circuit electrically connected in series with the first sub-circuit and to the other of the first and second ports, the second sub-circuit including an energy storage device.
19. A vehicle as set forth in claim 18 wherein the non-linear device includes a diode.
20. A vehicle as set forth in claim 18 wherein the energy storage device includes a capacitor.
21. A vehicle as set forth in claim 18 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, and wherein a substantial portion of the first current flows through the non-linear device when the first current flows through the first sub-circuit.  
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22. A vehicle as set forth in claim 21 wherein the energy storage device charges when the first current flows through the second sub-circuit.
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23. A vehicle as set forth in claim 22 wherein the energy storage device discharges when the contactor is closed, wherein the energy discharged from the

energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein a substantial portion of the second current flows through the resistor when the second current flows through the first sub-circuit.

5        24. A vehicle as set forth in claim 18 wherein the non-linear device is a first diode, wherein the second sub-circuit further includes a second non-linear device, and wherein the energy storage device and the second non-linear device are electrically connected in parallel branches.

10      25. A vehicle as set forth in claim 24 wherein the first and second non-linear devices each includes a diode, and wherein the energy storage device includes a capacitor.

15      26. A vehicle as set forth in claim 24 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, and wherein a substantial portion of the first current flows through the first non-linear device when the first current flows through the first sub-circuit.

20      27. A vehicle as set forth in claim 26 wherein the energy storage device charges when the first current flows through the second sub-circuit.

25      28. A vehicle as set forth in claim 27 wherein the energy storage device discharges when the contactor is closed, wherein the energy discharged from the energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein the a substantial portion of the second current flows through the resistor when the second current flows through the first sub-circuit.

29. A vehicle comprising:
- a motor; and
- a control circuit operable to control the motor, the control circuit including a contactor circuit having a contactor, a first end and a second end, and a snubber circuit connected across the contactor circuit, the snubber circuit including
- 5                  a first port electrically connected to the first end of the contactor circuit;
- a second port electrically connected to the second end of the contactor circuit;
- 10                 a first sub-circuit electrically connected to one of the first and second ports, the first sub-circuit including a resistor and a first non-linear device electrically connected in parallel branches; and
- a second sub-circuit electrically connected in series with the first sub-circuit and to the other of the first and second ports, the second sub-circuit including a energy storage device and a second non-linear device electrically connected in parallel branches.
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30. A vehicle as set forth in claim 29 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, wherein a substantial portion of the first current flows through the non-linear device when the first current flows through the first sub-circuit, and wherein the energy storage device charges when the first current flows through the second sub-circuit.
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31. A vehicle as set forth in claim 29 wherein the energy storage device discharges when the contactor is closed, wherein the energy discharged from the energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein a substantial portion of the second current flows through the resistor when the second current flows through the first sub-circuit.
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32. A vehicle as set forth in claim 30 wherein the first and second non-linear devices each includes a diode, and where the energy storage device includes a capacitor.

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33. A method of suppressing arcing in a contactor circuit including a contactor having at least two contacts that make and break an electrical connection, the method comprising the acts of:

5 providing a snubber circuit including a first sub-circuit and a second sub-circuit electrically connected in series, the first sub-circuit including a first branch having a resistor and a second branch having a non-linear device, and the second sub-circuit including a storage device;

10 electrically connecting the first sub-circuit to one end of the contactor circuit;

15 electrically connecting the second sub-circuit to the other end of the contactor circuit;

20 breaking the electrical connection of the contacts;

25 generating a first current in response to the breaking of the electrical connection;

30 allowing a substantial portion of the first current to flow through the non-linear device; and

35 charging the energy storage device with energy of the first current.

34. A method as set forth in claim 33 and further comprising the acts of:

40 after the charging act, making the electrical connection of the contacts;

45 generating a second current in response to the making of the electrical connection, the second current flowing in an opposite direction of the first current; and

50 allowing a substantial portion of the second current to flow through the resistor.

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35. A method as set forth in claim 33 wherein the non-linear device includes a diode.

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36. A method as set forth in claim 33 wherein the storage device includes a capacitor.

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37. A method as set forth in claim 33 wherein the non-linear device is a first non-linear device, and wherein the second sub-circuit further includes a third branch having a second non-linear device and a fourth branch having the capacitor.

5       38. A method as set forth in claim 37 and further comprising the acts of:  
            breaking the electrical connection of the contacts a second time;  
            generating a second current in an opposite direction of the first current in  
response to the breaking of the electrical connection the second time;  
            allowing a substantial portion of the second current to flow through the second  
10     non-linear device; and  
            allowing a substantial portion of the second current to flow through the  
resistor.

15     39. A method as set forth in claim 38 wherein the storage device includes a  
capacitor.

40. A method as set forth in claim 38 wherein the first and second non-linear  
devices include a first and second diode, respectively.